



DREAM 2047

January 2002

Vol.4

Acc No: 1194

No. 4

VP News

Inside

Marathi Science Writers' Meet

In continuation of Vigyan Prasar's efforts to assess the state of popular science writing in different regional languages and to identify the problems faced by science communicators, a two-day meet (December 1-2, 2001) was organised in Mumbai. Earlier, similar workshops were held in Allahabad, Agartala, Dibrugarh and Manipal. The workshop at Mumbai was jointly organised by Vigyan Prasar and Marathi Vidnyan Parishad (MVP), Mumbai. Nearly 60 science communicators from different parts of Maharashtra participated in the workshop. A number of eminent science communicators attended the workshop. The workshop was inaugurated by Shri M.V. Kamath, a veteran journalist, and the President of Vigyan Prasar Society. The key-note address was delivered by Dr. Bal Phondke, a prolific science writer and former Editor of *Science Today* and former Director, National Institute of Science Communication. Dr. V.B. Kamble, Acting Director, Vigyan Prasar made a brief presentation of the activities of Vigyan Prasar. Shri A.P. Deshpande, Honorary Secretary, MVP, talked about various activities of MVP, one of the leading science organisations for popularisation of science in the country. MVP was founded in 1966. Today MVP has 37 branches. VP plans to bring out the proceedings of the meet in near future. The valedictory address was delivered by Shri Prabhakar Deodhar, President, MVP. The inaugural speech of Shri Kamath and a report on the workshop are reproduced below :

EDITORIAL

- ✦ Bosons - The Birds That Flock and Sing Together
- ✦ Top Science Discoveries in 2001
- ✦ Kariamanikkam Srinivasa Krishnan
- ✦ Interview with NPL Director, Dr. Krishan Lal
- ✦ National Physical Laboratory - Setting Standards
- ✦ Science Propagation through Marathi



Inaugural Speech of Shri M.V. Kamath*

Mr. President and distinguished invitees,

You can have no idea how proud and honoured I feel to be invited to chair the inaugural session of this august gathering of science writers. I am here today primarily in the capacity as President of Vigyan Prasar. Vigyan Prasar has been doing wonderful work in a variety of ways, much of it totally unknown to our fellow citizens. Many of you are no doubt aware of the range and magnitude of that work. For that matter I myself have been largely ignorant of the magnificent work being done in the field of science writing in Marathi under the aegis of the Marathi Vidnyan Parishad. I am deeply grateful to your Honorary Secretary, Shri



A section of the audience



(From L to R) S. Mahanti, A.P. Deshpande, M.V. Kamath, Bal Phondke and V.B. Kamble

VP News Contd. on Page....26

... think scientifically, act scientifically ... think scientifically, act scientifically ... think scientifically, act...

Looking Forward

Vigyan Prasar wishes its readers a very happy, prosperous and a peaceful 2002.

The year 2001 was remarkable for several landmark achievements in Science and Technology. We had the first global view of the genomic landscape of human beings. The surprising finding was that the difference in genomes of different races is minuscule, only 0.1 per cent, that is, 99.9 per cent of all human beings have the same DNA. This implies that there is no superior race on this planet! The Nobel for the year 2001 in Physics was given away for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms. But the observation of this new state of matter had to wait for nearly seven decades after its prediction by Albert Einstein using the statistics developed by one of the makers of Modern Physics, Satyendra Nath Bose. The year 2001, incidentally marked a hundred years of the Nobel Prizes ever since they were first given away in 1901. The other news that made headlines were the advances made in the field of stem cell research and the human cloning technology.

On the other hand, the memories of the devastating earthquake of Gujarat still continue to be fresh in our minds. Even after one year, rehabilitation of a large number of affected people still seems to be a distant dream. Then came the attacks on the World Trade Centre Towers on 11 September and even before we could reconcile with it, we were faced with the threat of anthrax attacks. The last straw was the attack on our parliament on 13 December. Indeed the year that has gone by has posed many difficult tasks and challenges before us. However, there were a few silver linings as well. Literacy in the country went up significantly. Nearly 65% of the people can read and write today, compared to 52% in 1991. More than three-fourths of the males and more than half of the females can read and write today. What is more,

there has been a net decline in the "absolute" number of illiterates during 1991-2001.

Through these columns, we have been highlighting the developments in the fields of science, technology and other spheres of human activity, and discuss their possible impact on our lives. We have also been raising pertinent issues from time to time – be it disaster preparedness / management, ways and means to tackle bio-terrorism, the role of science communicators in literacy campaigns and so on. There is no gainsaying the fact that science and technology must be employed for improvement of the quality of life – be it in the field of social and economic growth, literacy and education, higher production of food grains, or rehabilitation of those affected by natural calamities.

If we had a few events that were truly exciting during 2001, there were a few that almost changed our lives and mode of thinking through extremist acts. Such behaviour, irrational and unscientific as it is, does not benefit anyone. It can only take us backwards. Such acts, whatever the form, must be condemned and not allowed to repeat. We do hope that the science communicators and the members of the VIPNET Clubs help people see reason, and think rationally. Only then shall we be able to meet the challenges posed by the year gone by and look forward to a tomorrow that would bring us peace and prosperity.

We thank our readers for their continued support and interest. Indeed it is a joy to receive a letter from a young reader from Kerala who finds articles in *Dream-2047* inspiring, or a teacher in a remote village of Orissa who translates the articles in Oriya for his students! This is a powerful medium through which we would like to interact and exchange ideas / views with you. Please do write to us.

□ **V.B. Kamble**

Editor : V.B. Kamble

Vigyan Prasar

Address for : C-24, Qutab Institutional Area, New Delhi-110 016
correspondence Tel. : 6967532; Fax : 6965986
e-mail : vigyan@hub.nic.in
website : <http://www.vigyanprasar.com>

Bosons - The Birds That Flock and Sing Together

□ V.B. Kamble

"Never accept an idea as long as you, yourself, are not satisfied with its consistency and logical structure on which the concepts are based. Study the Masters. These are the people who had made significant contributions to the subject. Lesser authorities clearly bypass the difficult points" - Satyendra Nath Bose

Exactly a hundred years after the first Nobel Prize for Physics was awarded to Wilhelm Conrad Rontgen (1845-1923) in 1901, the Nobel Prize for the year 2001 was jointly awarded to Eric A. Cornell (b.1961), Wolfgang Ketterle (b.1957) and Carl Wieman (b.1951) of the U.S.A. for the achievement of the Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of such condensates. Indeed, Bose-Einstein condensate is a new state of matter. The 2001 Nobel Laureates have succeeded in having caused atoms to "sing in unison" - somewhat similar to light photons, or the quanta of light in a laser beam which have the same energy and oscillate together. To cause matter also to behave in this controlled way has long been a challenge for researchers - this is precisely what they achieved in 1995. It all started in 1924 when the Indian physicist Satyendra Nath Bose made important theoretical calculations regarding the behaviour of light particles - or photons as they are called. He sent his results to Einstein who extended the theory to a certain type of atoms. Einstein predicted that if a gas of such atoms were cooled to a very low temperature, all the atoms would suddenly gather in the lowest possible energy state. The process is similar to when drops of liquid form from a gas, hence the term condensation. However, seventy years were to pass before scientists succeeded in achieving this extreme state of matter. In this article, we shall briefly trace the great saga of the last seventy five years. We shall begin our story with Satyendra Nath Bose - one of the makers of the Twentieth Century Physics.

Satyendra Nath Bose

Satyendra Nath Bose (1894 -1974) was born on the New Year's Day, January 1, 1894, in Calcutta. His ancestral home was located in the village Bara Jagulia, in the District of Nadia, about 48km from Calcutta. Satyendra Nath was the only son and he had after him six sisters in succession. Satyendra Nath's schooling began at the age of five. At first he was put in the Normal School, which was close to his home. Later on, when the family moved to their own house at Goabagan, he was admitted to the neighbouring New Indian School. In the final year of school, he was admitted to the Hindu School. He passed his entrance examination (matriculation) in 1909 and stood fifth in order of merit. He next joined the intermediate science course at the Presidency College, Calcutta, where he came under the tutelage of such illustrious teachers as Jagadis Chandra Bose and Prafulla Chandra Ray. Meghnad Saha came from Dacca (Now Dhaka) and joined the Presidency College two years later. P.C. Mahalanobis and Sisir Kumar Mitra were a few years senior to this group. Satyendra Nath Bose opted for Mixed Mathematics for his B.Sc. and passed the examinations standing first in 1913. The same result was repeated in the M.Sc. Mixed Mathematics examinations in 1915.



Satyendra Nath Bose

It is said that the marks secured by Satyendra Nath Bose in his M.Sc. examination created a new record in the annals of the Calcutta University - which is yet to be surpassed! In 1914, at the age of twenty, Satyendra Nath Bose was married to Ushabati Ghosh, while she was only eleven. They had nine children. Two of them died in their infancy. In 1974, on his death, he left behind him his surviving widow, two sons and five daughters. Incidentally, both his sons studied engineering while most of his daughters had graduated before they were married.

Satyendra Nath Bose was a scientist of varied interests and had an artistic bent of mind. Besides English, he was equally at home with French, German and Italian. Hugo, Goethe, Buddha and Sanskrit classes gave him inspiration and pleasure, while Rabindra Nath Tagore's writings cast a spell over him. After his M.Sc., he joined the Calcutta University as a research scholar in 1916 and started his studies in the theory of relativity. Next year, both he and M.N. Saha were appointed lecturers in Physics and Applied Mathematics Department of the University College of Science, Calcutta. Indeed it was an exciting era in the history of scientific progress. The quantum theory had just appeared on the horizon and important results had started pouring in. Saha and Bose translated the original papers of Albert Einstein (1879-1955) and H. Minkowsky (1864-1909) from German into English which were brought out in the form of a booklet entitled "The Principle of Relativity" by the University. Bose joined the Dacca university, which was founded in 1921, as Reader in Physics. Bose had carefully studied Max Planck's book entitled "Thermodynamik und Warmestrahlung". He knew about phase space and Boltzmann statistics from Gibbs' book: "Vorlesungen uber Gastheorie". He also knew about Einstein's deduction of Planck's formula and how he had never been satisfied with the derivation of this quantum law. Planck's condition ran counter to the classical ideas. Planck was aware of the difficulties, but he had never

been able to resolve them. He wanted to reconcile his theory with the classical theory. Bose wanted to solve the difficulty in his own way. How he achieved this, we shall presently see.

During his visit to Europe, Bose met a number of giant figures of that time like Paul Langevin, Madam Curie, Maurice de Broglie (Brother of Louis Broglie, who proposed that matter could behave as a particle as well as wave). Bose returned to Dacca some time during the latter half 1926 where he joined as Professor. He remained there from 1926 to 1945. His interest shifted from one problem to another - statistics, relativity and so on. He returned to Calcutta in 1945 to become the Khaira Professor of Physics in Calcutta University and stayed there till 1956. After a brief stint at Shantiniketan, he returned to Calcutta in 1958 when he was appointed National Professor.

He held this position until his death 16 years later. In his later years he became actively interested in popularization of science and took to writing on and about science in Bengali. For this purpose he founded the Bangiya Bijnana Parishad (Science Association of Bengal). He was extremely fond of instrumental music and played on the "Esraj" like a master. He was made a Fellow of Royal Society of London in 1958. He was a Foundation



Albert Einstein

Fellow of the Indian National Science Academy (1935).

At a function to celebrate his eightieth birthday, he said, "Well, after all, if one has lived through so many years of struggle, and if at the end he finds that his work has been appreciated, he feels that he does not need to live long. I think this is the faithful end to a long career." These words proved prophetic indeed. Only a few days later, he died on February 4, 1974. As a glowing tribute, the Department of Science and Technology, Government of India, in 1986 established the Satyendra Nath Bose National Centre for Basic Science in Calcutta.



Lev Davidovich Landau



Heike Kamerlingh Onnes

The Crucial Step

Bose set about thinking deeply and "spending sleepless nights" about the radiation problem. Next he took the crucial step in the identification of blackbody radiation as a photon gas. **He showed that the photons had a startling property of being strictly identical.** This led to a new expression for the thermodynamic properties of an assembly of photons in contrast to what one would have calculated on the then accepted basis, the so-called Maxwell-Boltzmann statistics. But with the "revolution" that Bose introduced into the counting process one obtains the correct thermodynamics of the photon gas. And that one step was the basis of a new synthesis between the wave and particle properties of photons; and, with it, the foundation of quantum field theory. Bose communicated this paper to the *Philosophical Magazine* in England. Unfortunately, no acceptance letter was received by him for a long time. And so, he sent a duplicate copy of the manuscript, which was entitled "Planck's law and light quantum hypothesis," to Einstein in Berlin, with a request to have it translated into German and published in the *Zeitschrift fur Physik*. The letter in Bose's own hand-writing is reproduced elsewhere. Einstein immediately translated Bose's paper into German and added the following note at the end: "Bose's derivation of Planck's formula appears to me to be an important step forward. The method used here gives also the quantum theory of an ideal gas, as I shall show elsewhere".

Bose's paper, translated by Einstein under the title "Planck's Gesetz und Lichtquanten-hypothese" was published in the August 1924 issue of *Zeitschrift fur Physik*. After Bose's paper came an avalanche of developments, the extension of Bose's theory to particles of arbitrary mass and non-zero chemical potential by Einstein (1924, 1925); the Fermi-Dirac statistics for electrons (1926), the quantization of the electromagnetic field by Heisenberg and Pauli (1929, 1930), and quantum electrodynamics by Dirac (1927, 1935). Both, Bose's theory, including Einstein's extension, and Fermi's theory were essentially statistical theories and dealt with complexions of the field. The actual construction of the wave functions which are symmetric and antisymmetric in the many particle systems was done by Dirac (1927). To find the relation

between particle type and the statistics which is obeyed was left to Pauli (1936, 1940), who showed that **integral spin particles obeyed Bose statistics and half integral spin particles obeyed Fermi statistics.** In modern relativistic quantum field theory, the spin-statistics theorem involving Bosons and Fermions is one of the most fundamental results. The applicational possibilities of quantum statistics were clearly demonstrated by Sommerfeld (1928), by introducing Fermi-Dirac statistics to metal physics. In the case of an ideal Bose gas with non-zero chemical potential,

there is a critical temperature, below which a finite fraction of gas condenses into a single quantum state. This condensed phase discovered by Fritz London in 1938 should exhibit superfluid properties. London also suggested that superfluid Helium should be related to this Bose-Einstein condensation phenomenon. Indeed, **Bose's work stands out as one of the central columns supporting the edifice of modern physics.** Bose, however, did not realise the immediate impact of this paper. We may note here that the term "photon" for the light quantum was given by the American chemist Gilbert Newton Lewis (1875-1946) in 1926.

The Photon Gas

We had described how Max Planck (1858-1947) derived the black body spectral distribution in these pages earlier (*Dream-2047*, June 2001). He considered a cavity containing the black body spectrum and postulated that all solid bodies, and therefore

the walls of the cavity, contained little oscillators - or the resonators as he called them - of every imaginable frequency. By resonators Planck meant small electrified particles which wriggled to and fro—surely, an assumption that is contrived and rather unaesthetic! Planck was forced to conclude that the energy levels of a material oscillator were quantised. Einstein analyzed the black body problem by considering radiation alone, and arrived at a conclusion that it was composed of quanta. He used this idea to explain the phenomenon of photoelectricity (*Dream-2047*, May 2001). The turning point for the photon idea came in 1923 with the discovery of the Compton effect. A photon

when scattered by material objects, say free electrons, loses a part of its energy with a consequent decrease in its frequency. With the discovery of the Compton effect (1923), all resistance to the photon idea evaporated. **It was realized that radiation had a dual character, that is wave-like and particle-like.** It was at this time when Bose entered the quantum arena and set out to derive Planck's law treating radiation as a gas consisting of photons. What Bose had essentially introduced was a new counting rule for the states of a gas of photons - or the quanta of light - that explained Planck's law of thermal radiation at one stroke.

While deriving Planck's law of black body spectral

"I had no idea.....!"

Bose did not realize the importance of the immediate impact of his paper on derivation of Planck's law which he sent to Albert Einstein in 1924 with a request to get it translated in German and submit it for publication in "Zeitschrift fur Physik". Years later, in 1975, this is what he said: "I had no idea that what I had done was really novel. I thought that perhaps it was the way of looking at the thing. I was not a statistician to the extent of the really knowing that I was doing something which was really different from what Boltzmann would have done from Boltzmann statistics. Instead of thinking of the light quantum just as a particle, I talked about these states. Somehow, this was the same question Einstein asked when I met him. How had I arrived at this method of deriving Planck's formula? Well, I recognized the contradictions in the attempts of Planck and Einstein, and applied the statistics in my own way, but I did not think that it was different from Boltzmann statistics".

Bose writes to Einstein

PHYSICS DEPARTMENT,
DACCA UNIVERSITY.Dacca, 16th June 1924.

Respected Sir, I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will be that (I have tried to deduce the coefficient $\frac{8\pi\nu^2}{c^3}$ in Planck's Law independent of the classical electrodynamics) only assuming that the elementary regions in the phase-space has the content h^3 . I do not know sufficient German to translate the paper. If you deem the paper worth publication I shall be grateful if you arrange for its publication in Zeitschrift für Physik. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request. The book has since been published. I was the one who translated your paper on Generalised Relativity.

yours faithfully
Sd/- Bose

Physics Department
Dacca University
Dated the 4th June 1924

Respected Sir,

I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that I have tried to deduce the coefficient $8\pi\nu^2/c^3$ in Planck's Law independent of classical electrodynamics, only assuming that the elementary regions in the phase-space has the content h^3 . I do not know sufficient German to translate the paper. If you think the paper worth publication I shall be grateful if you arrange for its publication in Zeitschrift für Physik. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request. The book has since been published. I was the one who translated your paper on Generalised Relativity.

Yours Faithfully

Sd/- S.N. Bose

distribution, what one tries to do is to derive an expression for the energy density, i.e. the radiation density in the frequency interval between ν and $\nu+d\nu$. Planck did this by starting with material oscillators which transferred their energy to standing waves in the cavity. In his analysis of Planck's work, Einstein supposed that radiation behaved like a gas of particles, and so he distributed the available energy E amongst these gas particles. He did not talk of gas particles; but considered photons as particles. Unlike Einstein, Bose did not regard his particles as distinguishable. Einstein did not make a big fuss about his particles being distinguishable or anything like that. In those days, nobody ever considered indistinguishable particles, and like everybody else, Einstein simply assumed (implicitly) that his particles were distinguishable. In addition, he forced agreement with experimental data at high frequencies. **Bose, on the other hand, treated photons to be indistinguishable.** Though not explicitly stated, the method he used for counting the number of possible arrangements of photons in different energy states implied this. Only later did people realize that he had taken a remarkable step. Further, Bose took into account the two states of polarization of the photon as well (that is, he took care of photon "spin"). **He tacitly assumed that photon number is not conserved.** Indeed, Bose himself had no idea that what he had done while deriving Planck's law was really novel (see Box). This was in the year 1924 when Quantum Mechanics had still not appeared on the scene. The photon had just been accepted. People did not know anything about spin, about Bosons and Fermions, and that they obeyed different statistics, and so on. All these developments occurred rapidly within the next few years. Many people made discoveries and every discovery influenced every other. It is against this background that we must view Bose's contribution to appreciate how it merged into the mainstream to contribute to the pool of knowledge.

Bose achieved two things ahead of quantum mechanics. First, he discovered indistinguishability. Indistinguishability is a natural product of quantum mechanics. But Bose sensed indistinguishability even earlier. Secondly, after people realised that quantum mechanics **demands** indistinguishability, it was found that there were two broad families of indistinguishable particles namely, Bosons and Fermions. After quantum mechanics came quantum statistical mechanics, which essentially deals with how quantum particles share energy at finite temperatures. By contrast, in the quantum mechanics as developed by Heisenberg and Schrodinger, there was no temperature. Hence, quantum statistical mechanics was the next step. Bose laid part of the foundation for quantum statistical mechanics even before quantum mechanics was born! We are now in a position to describe how a fixed total amount of energy is distributed among the various members of an assembly of

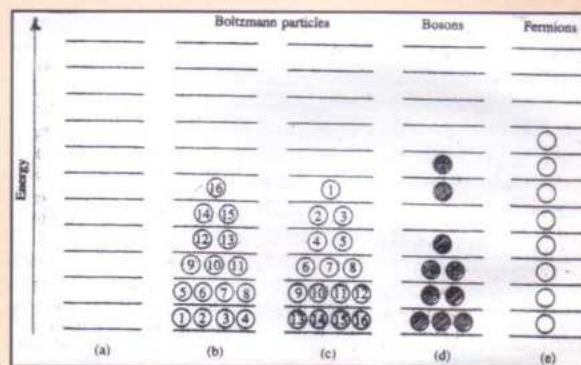


Figure 1 : Distribution of Boltzmann, Bose and Fermi particles, given the same choice of energy levels.

(Source: Bose and his Statistics by G. Venkatarman)

identical particles. For a conceptual understanding and completeness, we shall briefly outline how molecules of a gas, Bosons and Fermions behave following different statistics.

Molecules of a gas, Bosons and Fermions

We made a remark earlier that soon after the development of quantum mechanics, came quantum statistical mechanics, which essentially deals with how quantum particles share energy at finite temperatures. In any case statistical mechanics attempts to relate the macroscopic properties of an assembly of particles to the microscopic properties of the particles themselves. Statistical mechanics, as its name implies, is not concerned with the actual motions or interactions of individual particles; but investigates instead their **most probable behaviour**. While Statistical Mechanics cannot help us determine the life history of a particular particle, it is able to inform us of the likelihood that a particle (exactly which one we cannot know in advance) has a certain position and momentum at a certain instant. Because so many phenomena in the physical world involve assemblies of particles, the value of a statistical rather than deterministic approach is clear. Owing to the generality of its arguments, statistical mechanics can be applied with equal facility to classical problems (such as that of molecules in a gas) and quantum-mechanical problems (such as those of free

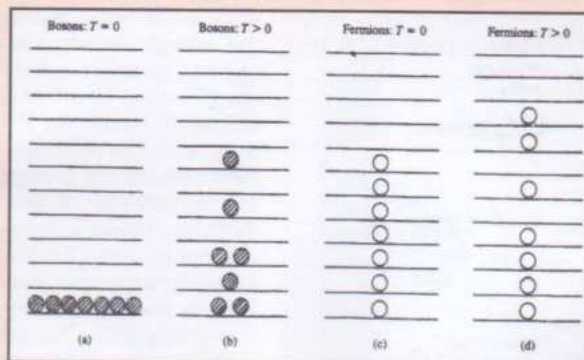


Figure 2: Bosons and Fermions

(Source: Bose and his statistics by G. Venkataraman)

not so with Fermions. Fermions obey a fundamental principle discovered by Wolfgang Pauli (1900-1958) in 1925 called the "exclusion principle", according to which **no two Fermions can exist in the same quantum state**. For electrons, it would mean that every electron in an atom occupying a particular quantum state cannot have any other electron in the same state.

So, given the same choice of energy states, how would "Boltzmann particles", Bosons and Fermions fill up these energy states? Behaviour of Boson and Fermions is shown in Figure 1. The figure shows that given the same choice of energy levels, the Boltzmann particles (a), the Bose particles (b) and the Fermi particles (c) can distribute themselves. The Boltzmann particles are distinguishable, and there is no restriction about how many of them can be accommodated in an energy level. The Bosons also have a lot of freedom and can in principle all crowd into a

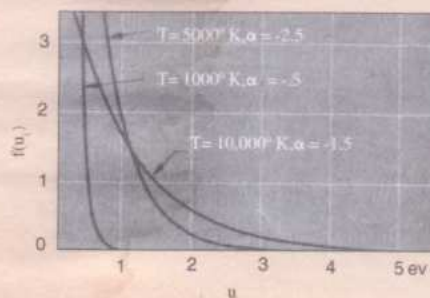


Figure 3: Maxwell-Boltzmann statistics

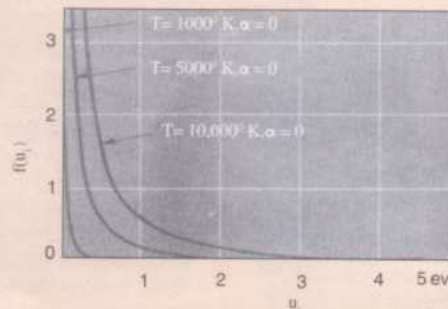


Figure 4: Bose-Einstein statistics

(Source: Concepts of Modern Physics, Arthur Beiser)

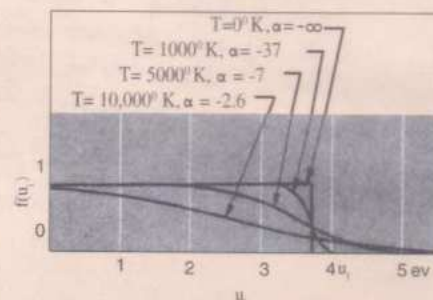


Figure 5: Fermi-Dirac statistics

electrons in a metal or photons in a box), and it is one of the most powerful tools of the theoretical physicist. We come across assemblies of three kinds of particles :

A. Identical particles of any spin that are sufficiently widely separated to be distinguished. The molecules of a gas are particles of this kind. Such "Boltzmann particles" follow the classical Maxwell-Boltzmann statistics (or distribution as it is called) while remaining distinguishable.

B. Identical particles of zero or integral spin that cannot be distinguished. These are Bose particles - also called Bosons - and do not obey the exclusion principle. They obey Bose-Einstein Statistics. Such particles include photons which have spin 1.

C. Identical particles with spin 1/2 that cannot be distinguished. These are Fermi particles - also called Fermions - and obey the exclusion principle. They obey Fermi-Dirac statistics. Such particles include electrons, protons, and several others.

We used two new terms while describing Bosons and Fermions, viz. spin and the exclusion principle. Let us describe what both mean. Spin refers to the "intrinsic" angular momentum possessed by the particle (independent of any orbital angular

momentum) it might have. One could crudely compare this situation with the Earth moving in its orbit around the Sun. Besides possessing orbital angular momentum as a result of its motion around the Sun, the Earth also spins about an axis passing through the poles, thereby possessing spin angular momentum. However, remember this is a very crude analogy. Quantum mechanically the situation is not so very simple.

What is important is to note that while any number of photons (spin 1) could be accommodated in any available quantum energy state, it is not so with Fermions. Fermions obey a fundamental principle discovered by Wolfgang Pauli (1900-1958) in 1925 called the "exclusion principle", according to which **no two Fermions can exist in the same quantum state**. For electrons, it would mean that every electron in an atom occupying a particular quantum state cannot have any other electron in the same state.

Nobel Prizes awarded for work with Bose-Einstein statistics, Bose-Einstein Condensation and Superconductivity

Here is a list of Nobel Prizes awarded for work with Bose-Einstein Statistics, BE condensation, and superconductivity. Although Bose did not receive the Nobel Prize, a large number of scientists received the prize for work based on his pioneering efforts that led to Bose-Einstein Statistics and eventually to Bose-Einstein condensation.

1913	Heike Kamerlingh Onnes	the Netherlands	in Physics for his investigations on the properties of matter of low temperatures which led, inter alia, to the production of liquid helium
1933	Erwin Schrödinger	Austria	in Physics for the discovery of new productive forms of atomic theory
	Paul Adrien Maurice Dirac	Great Britain	-do-
1962	Lev Davidovich Landau	USSR	in Physics for his pioneering theories for condensed matter, especially liquid helium
1972	John Bardeen	USA	in Physics for their jointly developed theory of superconductivity, usually called the BCS-theory
	Leon Neil Cooper	USA	-do-
	John Robert Schrieffer	USA	-do-
1973	Leo Esaki	Japan	in Physics for their experimental discoveries regarding tunneling phenomena in semiconductors and superconductors, respectively
	Ivar Giaever	USA	-do-
	Brian David Josephson	Great Britain	in Physics for his theoretical predictions of the properties of a supercurrent through a tunnel barrier, in particular those phenomena which are generally known as the Josephson effects
1978	Pyotr Leonidovich Kapitsa	USSR	in Physics for his basic inventions and discoveries in the area of low-temperature physics
1987	J. George Bednorz	Germany	in Physics for their important break-through in the discovery of superconductivity in ceramic materials
	K. Alexander Müller	Switzerland	-do-
1996	David M. Lee	USA	in Physics for their discovery of superfluidity in Helium-3
	Douglas D. Osheroff	USA	-do-
	Robert C. Richardson	USA	-do-
1997	Steven Chu	USA	in Physics for development of methods to cool and trap atoms with laser light
	Claude Cohen-Tannoudji	France	-do-
	William D. Phillips	USA	-do-
1998	Robert B. Laughlin	USA	in Physics for their discovery of a new form of quantum fluid with fractionally charged excitations
	Horst L. Störmer	Germany	-do-
	Daniel C. Tsui	USA	-do-
2001	Eric A. Cornell	USA	in Physics for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates
	Wolfgang Ketterle	Germany	-do-
	Carl E. Wieman	USA	-do-

$T = 0$ K. However, Fermions still keep aloof from each other and have single occupancy in each state.

The three distributions

Let us see how Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distributions look like. We shall not go into the details of calculations or the derivations of these distributions, but only give the expressions for them. In the formulas that follow, N_i is the number of particles which are in the state "i" with energy ϵ_i , g_i is the number of states that have the same energy ϵ_i . The three statistical distribution laws are as follows:

Maxwell-Boltzmann distribution :
The expression $N_i = g_i / e^{\alpha} \cdot e^{-\epsilon_i / kT}$ is called the the Maxwell-Boltzmann distribution followed by the molecules of a gas.

Bose - Einstein distribution : The expression $N_i = g_i / e^{\alpha} \cdot e^{-\epsilon_i / kT} - 1$ is called

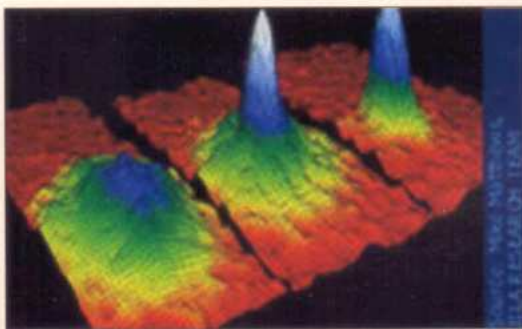


Figure 6: Bose-Einstein condensate observed experimentally. False-color images display the velocity distribution of the cloud of rubidium atoms at just before the appearance of the Bose-Einstein condensate, just after the appearance of the condensate, and after further evaporation left a sample of nearly pure condensate. The field of view of each frame is 200×270 micrometers, and corresponds to the distance the atoms have moved in about $1/20$ of a second. The colour corresponds to the number of atoms at each velocity, with red being the fewest and white being the most. Areas appearing white and light blue indicate lower velocities.

the Bose-Einstein distribution. When the total number of Bosons is conserved, i.e. when the number of Bosons does not change, α is non-zero. However, when we are dealing only with photons, their number is not conserved, i.e. it can change. Unlike the gas molecules or electrons, photons may be created or destroyed. α would then assume the value zero. Hence the expression would reduce to $N_i = g_i / e^{-\epsilon_i / kT} - 1$. While deriving Planck's law, the total radiant energy within the cavity must remain constant, however, the number of photons that incorporate this energy can change. This equation immediately leads to Planck's radiation formula once g_i is calculated following Bose's prescription of filling up the quantum states.

Fermi - Dirac distribution : The expression $N_i = g_i / e^{\alpha} \cdot e^{-\epsilon_i / kT} + 1$ is called the Fermi - Dirac distribution and incorporates the Pauli exclusion principle

explained earlier.

The quantity $f(u_i) = n_i/g_i$ is called the occupation index of a state of energy u_i , and is the average number of particles in each of the states of that energy. The occupation index does not depend upon how the energy levels of a system of particles are distributed, and for this reason it provides a convenient way of comparing the essential natures of the three distribution laws.

The Maxwell-Boltzmann occupation index is plotted in Fig. 3 for three different values of T and α . This Index is a pure exponential, dropping by the factor $1/e$ for each increase in u_i of kT . The Bose-Einstein occupation index is plotted in Fig. 4 for temperatures of 1000 K, 5000 K, and 10,000 K, in each case for $\alpha = 0$ (corresponding to a "gas" of photons). When $u_i \gg kT$, the Bose-Einstein distribution approaches the Maxwell-Boltzmann distribution, while when $u_i \ll kT$, the -1 term in the denominator causes the occupation index of the former distribution to be much greater. The Fermi-Dirac occupation index is plotted in Fig 5 for four values of T and α . The occupation index never goes above 1, signifying one particle per state, which is a consequence of the obedience of Fermi particles to the exclusion principle. At low temperatures virtually all of the lower energy states are filled, with the occupation index dropping rapidly near a certain critical energy known as the Fermi energy. At high temperatures the occupation index is sufficiently small at all energies for the effects of the exclusion principle to be unimportant, and the Fermi-Dirac distribution becomes similar to the Maxwell-Boltzmann one.



Eric A. Cornell



Carl E. Wieman



Wolfgang Ketterle

Bose-Einstein Condensation

It was Einstein who had an additional deep insight into the consequences of Bose's counting rule. In view of the fact that helium atoms have spin zero, they also would behave like a Boson gas. Bose-Einstein statistics can then be applied to study their behaviour. In the case of photons, the total number of particles actually decreases as we decrease the total energy of the system (equivalently, as we lower the temperature). However, if we apply Bose statistics to a gas of helium atoms in a box, we must obviously keep the number of atoms fixed as the temperature varies. So the precise formula for the number of atoms in a state with energy u_i is different from what Bose used in the case of photons as we have described earlier, though it looks very similar. It contains an additional term α as stated in the expression for the Bose-Einstein particles. This has the effect of subtracting a term from u_i . But, it has profound consequences. As the temperature is lowered, more and more particles pile into the lowest energy stated. (For the gas of photons, they just disappear from the system). At a low temperature, but one which is still above absolute zero, the answer for the number of particles in the lowest state becomes infinite. Here, we have Bosons behaving like birds that flock together!

Einstein realized that this infinite answer, though wrong, held the key to what was really happening in the gas as it was being cooled. He boldly said that one has to treat the lowest energy state as a separate entity from all the other states. All physical quantities would receive separate contributions from the lowest state, called the "condensate", and from all other states. In a Boltzmann gas the contribution of any single state,

even the one of lowest energy, is negligible because there are so many states which have nearby energies. But the Bose counting rule tilts the balance in favour of a finite fraction of the particles being in the lowest energy state, below the special value of the temperature which Einstein had calculated. Surely he had a deep conviction that Bose's counting rule was not just a trick to understand radiation but a new general principle.

When liquid helium is supercooled to temperatures below 2.1 K, it starts behaving in a strange manner. Its viscosity suddenly decreases, its heat conductivity is abnormally large. It behaves like a superfluid. In 1938, eminent quantum and statistical physicist Fritz London (1900-1954) suggested that the new properties exhibited by liquid helium were a consequence of Bose-Einstein condensation. Recent experiments, sixty years after London, show that his guess regarding liquid helium was right. This subject took another turn in 1995, when experimenters in the USA were able to produce a Bose - Einstein condensate for rubidium atoms.

Got it at last !

To achieve Bose-Einstein condensation, a gas must be cooled to less than one millionth of a degree above absolute zero. The 1997 Nobel prize winners (Steven Chu, Claude Cohen Tannoudji and William Phillips) had developed effective laser-based methods for cooling and trapping atomic gases, but the path to Bose-Einstein condensation remained extremely difficult. Carl Wieman (JILA and University of Colorado, Boulder, U.S.A.), pointed toward a successful method: laser cooling of alkali atoms in a so-called magneto-optical atom trap and then continued reduction of speed through evaporative cooling, which is a way of systematically getting rid of the fastest atoms. After extensive efforts by the research team in Colorado, Eric Cornell (at JILA and National Institute of Standards & Technology, Boulder, U.S.A.) solved the last remaining problem that prevented condensation. Cornell and Wieman produced a pure condensate of about 2000 rubidium atoms at an unbelievably low temperature of 20 nanoKelvin, i.e. 0.000 000 02 degrees above absolute zero. The successful experiments using rubidium atoms were reported in 1995 (Figures 6). Wolfgang Ketterle (Massachusetts Institute of Technology, U.S.A.) worked independently of Cornell and Wieman, and four months after them he reported large condensates of laser-cooled sodium atoms. Ketterle was able to demonstrate that the condensate actually behaved as a single coherent wave. He did an experiment similar to the one where two stones are thrown simultaneously at a calm water surface and their wave patterns roll into each other, strengthening and weakening each other in a systematic way. This is in greater contrast to what happens when uncoordinated matter, for example two fistfuls of sand, are thrown on the water surface. Ketterle was also able to extract a beam of coherent matter from the condensate, thus achieving the first-atom laser. An ordinary laser yields coherent radiation, an atom laser a stream of coherent matter. When a gas consisting of uncoordinated atoms turns into a Bose-Einstein condensate, it is like when the various instruments of an orchestra with their different tones and timbres, after warming up individually, all join in the same tone. Here we have Bosons not only behaving like birds that flock together, but also sing together!

After the pioneering experiments of 2001 Laureates, condensates have now been achieved by more than twenty additional research teams. Many fascinating applications are conceivable. Precision measurements utilizing slow atoms may offer big surprises: perhaps what we today call natural constants are completely constant. The new control over matter the Bose-Einstein condensation provides may have far-reaching practical applications, for example in lithography and nanotechnology.

References :

1. Satyendra Nath Bose
By S.D. Chatterjee
Biographical Memoirs (P. 59-79) , 1984
Indian National Science Academy, New Delhi
A highly readable account of life and work of S.N.Bose. This article partly draws on it.
2. Concepts of Modern Physics
Arthur Beiser
McGraw – Hill Book Company, 1967
A standard text book at undergraduate level, emphasizing the concepts as the title suggests.
3. Bose and his Statistics
By G. Venkataraman
Sangam Books Limited
By arrangement with Universities Press (India) Ltd., 1992
Hyderabad
A delightful book written in popular style with a number of anecdotes and related information. This article partly draws on it.
4. A Treatise on Heat
By M.N. Saha and B.N. Srivastava
The Indian Press (Publications) Private Ltd. (Fifth Edition) 1965, Allahabad.
A classic on heat and thermodynamics, written by a classmate of S.N. Bose and another luminary of Indian Science (M.N. Saha), and a colleague.
- First published in 1935.
5. S.N. Bose : The Man and his work
Part I : Collected Scientific Papers
Part II : Life, Lectures and Addresses
Published by S.N. Bose National Centre for Basic Sciences, Kolkata, 1994
The two volumes include all that Bose wrote – his research papers, articles and speeches.
6. <http://www.nobel.se>
A treasure-house on Nobel Laureates. Official website of Nobel Foundation.
7. <http://physicsweb.org/article/world/10/3/3>
Bose – Einstein Condensation (Feature March 1997)
A brief account of Bose- Einstein condensation leading to its observation in 1995.
8. The Story of Photon
N. Mukunda
Resonance (March 2000)
The article gives an account of the story of the light quantum from its inception in 1905 to its acceptance in 1924 in a lucid style. Resonance is a science journal at undergraduate level published by the Indian Academy of Sciences, Bangalore
9. Bose – Einstein Condensation
R. Nityananda
Resonance (April 2000)
A brief account of BEC. Lucidly written.
10. Bose – Einstein Condensation revisited
CERN Courier, IOP Publishing Ltd.
<http://www.cerncourier.com/main/article/41/10/17>
A good article covering historical details till the award of the 2001 Nobel Prize.
11. <http://jila.colorado.edu>
Website of JILA where Eric Cornell is a senior scientist at National Institute of Standards and Technology.

Bosons-The birds that flock and sing together : Glossary

Important terms used in connection with Bose-Einstein Statistics are given below. The terms given do not necessarily appear in the present article.

Angular momentum : The cross product of a vector from a specified reference point to a particle, with the particle's linear momentum. Also known as moment of momentum.

Bardeen-Cooper-Schrieffer theory : A theory of superconductivity that describes quantum-mechanically those states of the system in which conduction electrons cooperate in their motion so as to reduce the total energy appreciably below that of other states by exploiting their effective mutual attraction; these states predominate in a superconducting material. Abbreviated BCS theory.

Bose-Einstein condensation : A phenomenon that occurs in the study of systems of bosons; there is a critical temperature below which the ground state is highly populated. Also known as condensation; Einstein condensation.

Bose-Einstein distribution : For an assembly of independent bosons, such as photons or helium atoms of mass number 4, a function that specifies the number of particles in each of the allowed energy states. Also known as Bose distribution.

Bose-Einstein statistics : The statistical mechanics of a system of indistinguishable particles for which there is no restriction on the number of particles that may exist in the same state simultaneously. Also known as Einstein-Bose distribution.

Bose gas : An assemblage of noninteracting or weakly interaction bosons.

Boson : A particle that obeys Bose-Einstein statistics; includes photons, pi mesons, and all nuclei having an even number of particles and all particles with integer spin.

Cooper pairs : Pairs of bound electrons which occur in a superconducting medium according to the Bardeen-Cooper-Schrieffer theory.

Exclusion principle : The principle that no two Fermions of the same kind may simultaneously occupy the same quantum state. Also known as Pauli exclusion principle.

Laser : A device that uses the principle of amplification of electromagnetic waves by stimulated emission of radiation. Derived from light amplification by stimulated emission of radiation.

Liquid helium : The state of helium which exists at atmospheric pressure at temperatures below -268.95°C (4.2K), and for temperatures near absolute zero at pressures up to about 25 atmospheres; has two phases, helium I and helium II.

Maxwell-Boltzmann distribution : A function giving the probability (or some function proportional to it) that a molecule of a gas in thermal equilibrium will have values of certain variables within given infinitesimal ranges, assuming that the gas molecules obey classical mechanics, and possibly making other assumptions.

Maxwell-Boltzmann statistics : The classical statistics of identical particles,

as opposed to the Bose-Einstein or Fermi-Dirac statistics. Also known as Boltzmann statistics.

Phase space : For a system with n degrees of freedom, a Euclidean space with $2n$ dimensions, one dimension for each of the generalized coordinates and one for each of the corresponding momenta.

Photon : A massless particle, the quantum of the electromagnetic field, carrying energy, momentum, and angular momentum with spin angular momentum 1. Also known as light quantum.

Photon gas : An electromagnetic field treated as a collection of photons; it behaves as any other collection of bosons, except that the particles are emitted or absorbed without restriction on their number.

Photon theory : A theory of photoemission developed by Einstein, according to which a light beam behaves like a stream of particles (called photons) when it delivers energy to a substance displaying photoemission, the particles each having an energy equal to Planck's constant times the frequency of the light.

Planck oscillator : An oscillator which can absorb or emit energy only in amounts which are integral multiples of Planck's constant times the frequency of the oscillator. Also known as radiation oscillator.

Planck radiation formula : A formula for the intensity of radiation emitted by a blackbody within a narrow band of frequencies (or wavelengths), as a function of frequency, and of the body's temperature. Also known as Planck distribution law; Planck's law.

Planck's constant : A fundamental physical constant, the elementary quantum of action; the ratio of the energy of a photon to its frequency, it is equal to $6.62620 \pm 0.00005 \times 10^{-34}$ joule-second. Symbolized h .

Planck's law : A fundamental law of quantum theory stating that energy associated with electromagnetic radiation is emitted or absorbed in discrete amounts which are proportional to the frequency of radiation.

Statistical mechanics : That branch of physics which endeavors to explain and predict the macroscopic properties and behaviour of a system on the basis of the known characteristics and interactions of the microscopic constituents of the system, usually when the number of such constituents is very large. Also known as statistical thermodynamics.

Statistics : A discipline dealing with methods of obtaining data, analyzing and summarizing it, and drawing inferences from data samples by the use of probability theory.

Steady state : The condition of a body or system in which the conditions at each point do not change with time, that is after initial transients or fluctuations have disappeared.

Superconductivity : A property of many metals, alloys, and chemical compounds at temperatures near absolute zero by virtue of which their electrical resistivity vanishes and they become strongly diamagnetic.

Superconductor : Any material capable of exhibiting superconductivity; examples include iridium, lead, mercury, niobium, tin, tantalum, vanadium, and many alloys. Also known as cryogenic conductor; superconducting material.

Superfluid : A collection of particles which obey Bose-Einstein statistics and are all in the lowest energy state allowed by quantum mechanics, having zero entropy and zero resistance to motion; examples are a fraction of the atoms in liquid helium II and a fraction of the pairs of electrons in a superconductor.

Superfluidity : The frictionless flow of liquid helium at temperatures very close to absolute zero through holes as small as 10^{-7} centimeter in diameter, and for particle velocities below a few centimeters per second.

• • •

Top Science Discoveries in 2001

Year 2001 has gone by. But it was witness to a number of important happenings in science and technology. Year 2001 was the 100th anniversary of the Nobel prizes. A lot of discoveries and inventions have taken place in this year. Below is a quick review of important stories, some are because of their significance and others just because they are 'fun'.

Spintronics

Nearly every electrical and electronics gadget is based on electron's property, in which negative charge plays a very important role. But apart from charge, electrons possess another fundamental trait namely spin - that could give rise to whole new class of electronic devices. During last year, scientists made several advances in the field-finding way to create "spin polarized" electric current in semiconductors, pass electron spin from one semiconductor to another, and spin electrons using electricity.

Stopping light in its tracks

In January, two independent teams of scientists announced that they had found a way to reduce the speed of light to zero. Although light in a vacuum moves at a neck-breaking 186,000 miles per second, materials with a high refractive index can slow it down. This has ample uses, in quantum computers.

World's Most Accurate Clock

Since 1967 scientists have defined a single second according to microwave frequency transitions in Cesium, "ticks" that occur roughly once each nanosecond. Optical transitions in atom take place more frequently and can meter out smaller divisions of time. But until recently, researchers had no way to the faster ticks. In July 2001 physicists devised the first ever all-atomic clock, allowing them to divide time down to the femtosecond.

Human Cloning

On October 13, 2001 scientists at Advanced Cell Technology came into their laboratory to see under the microscope what they had been striving for months — little balls of dividing cells not even visible to the naked eye. As they appeared, the specks were precious because they were, according to ACT, the first human embryos produced using the technique of nuclear transplantation, popularly otherwise known as cloning.

Human Genome Analysis

The world celebrated when scientists from the Human Genome Project, an international consortium of academic research centre, and Celera Genomics, a private U.S. company, both announced that they had finished working drafts of the human genome in 2000. But these drafts revealed only the beginning of the story. In February 2001 both teams announced the results of their initial analysis which revealed among other surprises, that humans have a mere 26,000 to 40,000 genes or far fewer than people predicted.

• • •

Compiled by : Kapil Tripathi

VP News Contd. from Page....36

A.P. Deshpande, for briefing me on this score.

I am addressing you in English, but I have Shri Deshpande's permission to do so. Unfortunately neither my science, nor my Marathi, is equal to addressing you in Marathi though I have a basic degree in science and I live in Mumbai.

Not long after I was appointed President of Vigyan Prasara I learnt to my delight that the energetic staff of Vigyan Prasara had organised a meeting of science writers in Assamese and north east languages in Guwahati and that it had a tremendous response. I then wondered whether it was possible to arrange a similar seminar in the south as well, covering writers in Tamil, Telugu, Kannada and Malayalam.

I happen to be a member of the executive of the Manipal Academy of Higher Education (MAHE) as well as Honorary Director of the Manipal Institute of Communication and I said we could provide all the necessary infrastructure at a very reasonable cost. Vigyan Prasara was quite taken up by the idea; what is more, there was a very positive response from science writers in the four south Indian languages. And, I am pleased to say, the seminar that Vigyan Prasara organised in due course, was a major success.

At that point I suggested that we should organise a similar seminar in Mumbai to cover science writing in Marathi and Vigyan Prasara was again most receptive to the idea. I had then no knowledge whatsoever of either the existence of Marathi Vidnyan Parishad or of the great work it has been pasty doing. It merely shows how distanced many of us are from our own language culture. We live in an English cocoon and our world is circumscribed by English. For that reason I feel ashamed - and I mean it - and apologise to your for my ignorance.

Having said that, I would like to make a couple of points before inviting Dr. Bal Phondke to deliver his keynote address.

First of all I am presuming that not only are Marathi writers on science thinking in Marathi but are also contributing original work in Marathi. This is not to say that I am against translation of English science works into Marathi. But I would be proud to think that we are fully capable of scientific thinking in our own *matri bhasha*. If German science writers can think in German, Russians in Russian and Japanese in Japanese, why should we be dependent on English even if we are to concede that most science writing we are exposed to is in English? And, if at all it is possible, I would like these writings in Marathi, then translated into English and offered to English language papers as Marathi thinkers' contribution to the edification of English readers.

That leads me to think that perhaps Marathi Vidnyan Parishad should also think of having a body of translators to translate articles in Marathi not into English alone, but into several other Indian languages. Why should Marathi genius be confined only to the Marathi-speaking diaspora? Why shouldn't it be available to people speaking different languages including Hindi, Bengali, Gujarati, Telugu, etc. In fact, perhaps, Vigyan Prasara should set up a House of Translators so that the best in any Indian language is made available to readers of all Indian languages. I suppose we will have to work out how cost-effective such an organisation would be. Would there be enough multi-linguists who can do a good job of translating an article in one language into another sufficiently well, to make it acceptable to readers of another language?



Mr. M.V. Kamath addressing the Audience

even to those who know Sanskrit? I remember how many people used to laugh at the term 'Kanta Langoti' to describe a neck tie. We don't need to make ourselves ridiculous.

And yet I remain perplexed. Living as we do in as Anglicised world, I can't imagine cutting ourselves from it completely. Can we - should we - apply ourselves to translate all scientific words into their Sanskrit equivalents? Or would be it wise and sane on our parts to let carboxy methyl cellulose be referred to as carboxy methyl cellulose and nothing else? Where does one draw the line?

Medical texts abound in words that offer a challenge to the translator. What applies to medical terminology applies just as well to terminologies of all scientific subjects. That is why I am looking forward to hearing many experts who are assembled here today and to learn from them, and get to know their views. May I say that in the very act of meeting here today we are creating history? It is my earnest wish that out of this seminar will emerge certain approaches to the writing of science that will be of universal value. And may I say how grateful I am to the Marathi Vidnyan Parishad for offering to organise this seminar. I thank you, Shri Deshpande with all the sincerity at my command.

I am looking forward to the day when a student can get a Ph.D by writing his thesis in Marathi. We should aim at producing science writing in Marathi to Himalayan heights. It is one thing to 'popularise'

science and promote a scientific outlook. But it is quite another to make Marathi -- for that matter, any other Indian language - a vehicle for communicating the most abstruse scientific thought and concerns. I am not being jingoistic. I fully realise and appreciate the role of English in science communication. Trying to do away with English is wishful thinking. But surely we as a people can rise to heights undreamt of by our forefathers many of them from Charaka onwards or sideways of great eminence?

From this seminar, I hope, certain concepts will rise that could serve as a guide for the future.

Thank you again, Mr. President and may I wish this seminar the success it so richly deserves.

*M.V. Kamath

Kallyanpur House, 3rd Road, Khar (W), Mumbai 400052

...



Mr. Prabhakar Deodhar addressing the Audience

Kariamanikkam Srinivasa Krishnan

□ Subodh Mahanti

It is better — much better — to have wisdom and knowledge than gold and silver.

Proverbs, xvi, 16

What is remarkable about Krishnan is not that he is a great scientist but something much more. He is a perfect citizen, a whole man with an integrated personality.

Jawahar Lal Nehru

Sir K.S. Krishnan won his scientific spurs by opening peep-holes into the interiors of molecules. One such peep-hole was provided by his collaboration in the discovery of the Raman Effect (C.V. Raman was his mentor and guide at the time). Another was the invention of an ingenious experimental technique to establish correlations between the magnetic properties of crystals and their internal architecture. A third was the mapping of the energy distribution of electrons in graphite crystals. Lest one should imagine that all this was the pastime of a curious mind, with little or no practical consequence, I must hasten to add that the present flood of synthesis — from dyes and drugs, paints and plastics to fuels and fabrics — is the outcome of a deeper knowledge of the solid state of matter acquired through these and allied techniques.

Jagjit Singh in *Some Eminent Indian Scientists*

Kariamanikkam Srinivasa Krishnan (KSK) is mostly known as co-discoverer of the famous Raman effect, a discovery which brought the first and till date the only Nobel Prize in Science to India. The Prize was awarded to Krishnan's mentor and research guide C.V. Raman in 1930. A lot of unnecessary controversies were raised and still continue to be raised on the point that KSK was not given due credit for his part in the discovery. In fact some have even gone to the extent that it was KSK who had discovered the Raman Effect and Raman took the entire credit for it. But Krishnan himself had no grievance for it. KSK, in one conversation with S. Ramaseshan, had said: "It is a blatant misrepresentation. The best I can say is that I participated actively in the discovery...." On being asked that Raman was being accused of taking away the lion's share of the credit of the discovery KSK replied, "...that is another misrepresentation. Professor never tried to do this. If you read the Nobel lecture, which is a true and honest account of the progress and history of the subject, Professor names all his collaborators in order starting with K. R. Ramanathan giving everyone (and including me) his due credit. Again and again in public lectures he always mentioned that I collaborated with him in the discovery of the effect and that our collaboration was similar to that of Bowen and Millikan which was praise indeed".

It was also pointed out by Krishnan that while recommending Krishnan for a professorship at the Andhra University Raman wrote to the Vice Chancellor, "If the Nobel Award for physics made in 1930 had been for the work done in the year 1928 alone instead of the entire work on the scattering of light done at Calcutta from 1921 onwards, Krishnan could justly have come in for the share of the prize." The citation for the Nobel Prize also stated that the Prize was given to Raman for his work on the scattering of light and the discovery of the effect named after him. In reality there is no controversy. It was Raman who deserved the Prize. In this connection it is worthwhile to note from the preface by G. Baskaran of the Institute of Mathematical Science, Chennai.

to the Special Section on K.S. Krishnan Birth Centenary in *Current Science*. Baskaran wrote: "It is my personal opinion, that Raman-Krishnan controversy is no controversy... Raman, a great scientist, was in a tireless pursuit of an important phenomenon and was fortunate to get a young and great student like KSK. A careful look at KSK's diary as reported in G. Venkataraman's book and a host of other factors clearly illustrate this — Raman deserved the Nobel Prize for the Raman effect. And the then young Krishnan grew into a great scientist on his own right." This fact that Krishnan himself was a very distinguished scientist in his own right and not to be remembered only because he was co-discoverer of Raman effect needs to be highlighted.

KSK was an outstanding physicist of international repute. He made pioneering contributions in a number of fields of physics. He had the ability to recognize and exploit connection between phenomena in different fields of physics.

KSK played an important role in the development of science and technology in India. He was deeply associated with the premier scientific/educational organizations in the country like the Atomic Energy Commission, the Council of Scientific and Industrial Research and the University

Grants Commission. He was a great teacher, a real guru in the tradition of great ancient sages. Besides being a 'complete physicist' he was 'a whole man with an integrated personality'. He was a staunch nationalist. He forcefully championed the cause of science writing in mother tongue. He himself ably performed the task in Tamil. He was a distinguished writer in Tamil. Thus G. Baskaran wrote: "Conveying the essence of science and its excitement in an understandable way to a layman or a non-expert is an art that few scientists have mastered. This has its very important role and value in society. It is also an important duty of the science community that is being neglected in modern times. KSK had this skill as it is clear from his many articles on science and related issues in Tamil and English as well as the talks that he has given in All India Radio. He was an ardent spokesman for science."



K.S. Krishnan

KSK strongly believed that one can convey even very complicated scientific facts in his mother tongue. His scholarship and appreciation of Tamil literature must have given the gift to perform this task with ease. In one of his articles he speaks of his school science teacher Thirumalai Kozhunthu Pillai, who enthused the students by teaching science in a understandable way in chaste Tamil. Listening to him he got the conviction that difficult scientific concepts could be conveyed in Tamil.

He was an sports enthusiast and played tennis, bridge and football. He had mastery over Sanskrit and Tamil literature. Inspired by his father, KSK since his childhood developed an abiding love of religion and Indian philosophies. Many people have noted that it was a pleasure to listen him. He could always find an appropriate anecdote to drive home a moral or disarm a critic or just to entertain'.

KSK was born on 4 December 1898, in the village of Wartrap, in the Ramnad (then Tirunelveli) District of Tamilnadu (then a part of the Madras Presidency). His father was a school teacher. After schooling in his village school and at the Hindu High School at the neighbouring town Srivilliputtur he studied in the American College, Madurai and Christian College Chennai (then Madras). KSK's interest for science grew in his school days. To quote Krishnan : "My first love for science came in my fourth form (class 9) in my high school in 1911. Even though my teacher was not a professional scientist, he was good at explaining science in a clear and captivating fashion. His lessons not only sunk deep into our mind but also made us crave for more science. Whether it is physics, geography or chemistry, his teaching style was unique. He did not simply reproduce the lessons from the book. He demonstrated many simple experiments for us and also encouraged us to do experiments ourselves. Very few teachers I know are of this type, and I feel fortunate to have had him as my first science teacher... My real involvement in science came after a year, when my physics teacher asked us to write an "essay" about an instrument that I constructed on my own, for measuring the density of solids. A few days later I learned that my instrument is nothing new and it was invented by Nicholas many years ago. "The Nicholas hydrometer" was by then text book material."

After taking a master degree in physics KSK became a demonstrator in chemistry. Here, at the request of some of his students, KSK organized an informal lunch-hour discussion where the students were free to discuss any question in physics, mathematics or chemistry. It became so popular that students from nearby colleges started attending it. Often the big gallery of the lecture room used to be full to over flowing. G. Venkataraman in his book, *Journey Into Light : Life and*



M.N. Saha

Science of Raman, a marvellous biography of Raman has written : "Krishnan took a master's degree in physics but the only opening then available to him was a Demonstrator in chemistry in Madras Christian College. During this period, Krishnan ran an informal but highly successful lunch-hour discussion on diverse topics in physics and chemistry which soon began to attract participants from other colleges as well. One beneficiary later remarked that he had learned more physics from the lunch-break seminars than from regular class-room lectures."

In 1920, Krishnan went to work with C.V. Raman at the Indian Association for the Cultivation of Science, Kolkata (then Calcutta).

About his joining Raman's research group, Krishnan later wrote : "I relinquished the small job I had and decided to do research in physics and went to Prof. C.V. Raman at Calcutta. But, he did not agree for my starting research immediately. Only after learning various aspects of physics properly at Calcutta University for two years was I able to join his research group. I had the good fortune of having a five year "Gurukula Vasam" there. These five years turned out to be a festive season in my science life". KSK worked very hard. It is said that his work in the laboratory began at 6 a.m., often after an early walk and an cold bath. But his interests were not confined to research

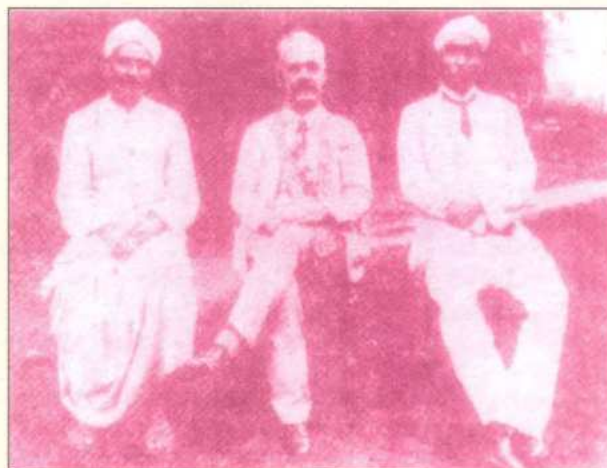
alone. He also studied a lot of literature, religion and philosophy. One will get a glimpse of the breadth of Krishnan's reading habit and his source of his inspiration from the following remarks made by Krishnan in a radio broadcast :

"Walter Scott, Dickens, Thackeray, Stevenson, Cervantes, Dumas and Victor Hugo and Conan Doyle linger in my memory as my favourite authors at this time, Plato and Aristotle in translations, Shakespeare, Milton and Shelley, Swift, Addison, Boswell, Newman, Mathew Arnold, Walter Pater and Charles Lamb at a later age and Tolstoy, Ibsen and Bernard Shaw

still later. Some of them naturally stand out much more prominently than others in my memories. I should specially mention *Don Quixote*, *Pickwick Papers*, *Vanity Fair* and *Book(s) of Snobs*, *Essays of Elia*, *Essay and Discourses* of Stuart Mill, some of the prose writings of Swift and Whitehead, *Allice in Wonderland* and *Through the Looking Glass*, most of which I have re-read later.

Among the popular scientific books that made a great impression on me I should specially mention Tyndall's *Fragments*, *Microbe Hunters* by Paul de Kruif, *Men of Mathematics* by Eric Bell, *A Mathematician's Apology* by Hardy and the biographies of Kelvin, Helmholtz, Lord Rayleigh, Maxwell and Tait.

Among the serious scientific writings, the collected papers of Lord Rayleigh have been my constant companion for nearly



K.S. Krishnan, Arnold Sommerfeld and C.V. Raman

38 years and I cannot think of a better model for a research worker. One of the research papers of Einstein I have read off and on during the same period, and every time by read it I get something new out of it. Some of the papers of Niels Bohr had over me even more profound influence."

Besides his research work and general reading he also took active interest in sports. He was a good football player. And he was a frequent visitor to the Eden Gardens for watching a football match. He used to play bridge and also tennis. He used to take a very lively interest in political movement. But all this did not affect the quality or quantity of his scientific work. At the instance of Raman he engaged himself in experimental study of the scattering of light in a large number of liquids, and its theoretical interpretations. He played a significant role in the discovery of Raman Effect. It is important to note that though Krishnan played an important role in the discovery the Raman Effect he did not pursue this subject in later part of his career. He worked in fields like magnetism, thermal conductivity and thermionics.

Arnold Sommerfeld visited Calcutta in October 1928 to give lectures on 'Modern Developments in Wave Mechanics'. KSK assisted Sommerfeld to prepare a book based on the lectures for publication by the Calcutta University. It was not just simply reproduction of the lectures. He developed the lectures in an independent and original way, supplying new and elegant mathematical proofs. Sommerfeld commended for KSK's originality and scholarship. In fact it is said that Sommerfeld offered to publish the book under joint authorship. However, the offer was politely declined by KSK.

In December 1928 KSK moved to the Dacca University (now in Bangladesh) as the Reader of in the physics Department. At the time Satyendra Nath Bose was the Head of the Physics Department. In Dacca University he studied magnetic properties of crystals in relation to their structure. In the process KSK developed elegant and precise experimental technique to measures the magnetic anisotropy of dia - and paramagnetic crystals. The research papers published by KSK and his colleagues from Dacca University are considered to be foundation stones of the modern fields of crystal magnetism and magneto chemistry. In 1933 KSK came back to Kolkata to take up the post of Mahendralal Sircar Professor of Physics in the Indian Association for the Cultivation of Science. He continued to study of magnetic properties of crystals in relation to their structure.

In 1937, KSK was invited by Lord Rutherford to the Cavendish Laboratory, Cambridge, and by Sir William Lawrence Bragg to the Royal



Charles Dickens



John Milton



George Bernard Shaw



Percy Bysshe Shelley



Alfred North Whitehead



Jan Hasbrouck Van Vleck

Institution, London, to give lectures.

In 1942, KSK moved to Allahabad University as Professor and Head of the Department of Physics. He succeeded Meghnad Saha. Here he took up the physics of solids, in particular metals.

In 1948, KSK took over the directorship of the National Physical Laboratory (NPL) set up by free India as one of the national laboratories under the aegis of the Council of Scientific and Industrial Research (CSIR). In NPL, besides carrying out his administrative responsibilities, he continued his activities in his chosen fields of research. He also turned his attention to problem in the thermionics, a branch of electronics dealing with the emission of electrons from matter under the influence of heat.

KSK received a number of honours both in India and abroad. In 1948 he became the General President of Indian Science Congress. The title of *Padma Bhusan* was awarded to him by the Govt. of India in 1954. In 1955, the US National Academy of Science invited KSK to be the guest speaker at their Annual Dinner. He was specially flown over to America for the purpose. It was a rare privilege. Earlier this privilege was enjoyed by only the Presidents of the Royal Society of London, of the Royal Netherlands Academy and of the Swedish Academy. Here he delivered a lecture on cultural values in technical education. Jan Hasbrouck van Vleck (1899-1980), pioneer in the development of modern quantum mechanical theory of magnetism and who got Nobel Prize in 1977 commented on this lecture. "He (Krishnan) quoted extensively from Whitehead and it was his speech that prompted me to read some of Whitehead's writings." Alfred North Whitehead (1861-1947), the British mathematician, physicist and philosopher, pioneered (alongwith Bertrand Russel) in mathematical logic and foundations of mathematics.

He was elected a Fellow of the Royal Society of London in 1940. He was Knighted in 1946. In 1956, he was elected a Foreign Associate of the US National Academy of Sciences. KSK was the first recipient of the Bhatnagar Memorial Award in 1961. The Govt. of India made him a National Professor.

KSK was a founder member of the International Union of Crystallography. Among the other members were Max Theodor Felix Von Laue (1879-1960) and William Lawrence Bragg (1890-1971). He was President of the National Academy of Sciences and also of its predecessor National Institute of Sciences of India. He was the Vice President of the International Union of Pure and Applied Physics and International Council of Scientific Unions.

Contd. on page 20

Interview with NPL Director, Dr. Krishan Lal

Dream 2047: Sir, NPL, one of the constituent laboratories of the Council of Scientific and Industrial Research (CSIR), carries a rich legacy of Dr. K S Krishnan. Can you tell us about some of the major contributions NPL made to Indian science and technology?

Dr. Lal: Primarily, NPL was set up with a mandate of establishing national standards for measurements and carrying out research in areas of physics, which are relevant to the national needs and are of topical interest from global perspective. It might be interesting to note that there were about 500 systems of measurements in India at the time of Independence. NPL had to develop a uniform standards system for India, which was as per international practice in industrialized nations. This was to ensure that there would not be any discrepancy in measurement in any part of the country. Having established the standards, it has to maintain them and upgrade them from time to time. In a way, NPL had to spearhead a quality movement, which was essential for industrialization in the country. It was the wisdom of India's first Prime Minister Pt. Jawaharlal Nehru that prompted India to adopt a uniform standards system immediately after Independence. In 1956, India adopted the Metric system of standards. In recent times, the advent of ISO certification and a keen interest shown by an increasing number of Indian industrial houses in this certification has led to deeper professional interest in conforming to the established measurement systems.

Internationally, calibration and standards has not been a static field. Every time a new discovery is made in physics or chemistry, there is a flurry of activity to find out whether it can be used for improving measurement accuracies. For instance, the definition of unit of resistance, Ohm, underwent a major change after the discovery of Quantum Hall Effect, which won the German scientist Prof. Klaus Von Klitzing the Nobel Prize in physics. Recently, attempts are on to improve realization of the unit of time, the second, through laser cooling of atoms so that accuracy of second can further be improved by 100 times. Currently, the cesium atomic clocks have an accuracy of about 10^{-14} . NPL has been perusing research in standards particularly in the field of time and frequency, radiation measurements and quantum metrology.

Dream 2047: Apart from the field of calibration and standards, what are the other areas NPL is working on?

Dr. Lal: I was coming to that. Calibration and standards constitutes only one-third of NPL's activity. Other areas are material science, materials characterization, radio and atmospheric science and superconductivity & cryogenics. In materials science, NPL's work on carbon fibres and composites is quite well known. Very recently, NPL scientists developed a metallic tube for the landing gear of the Advanced Light Helicopter (ALH), one of the prestigious defence projects, being executed by the Hindustan Aeronautics Limited (HAL). It is currently being validated. Another one is research on phosphors. Worldwide, there is an interest in increasing the light retaining power of phosphors. This property of phosphors

has tremendous applications. Similarly, NPL scientists have been working in the area of thin film technology too. Besides, NPL has been associating with various space technology programmes where an attempt is on to replace aluminum with a light-weight metal, magnesium, to save on mass of the launching vehicles.

Our Materials Characterization Group is perhaps the best in the country. Even in the world, not many laboratories are doing better work in materials characterization than NPL. NPL's work on methane emission was instrumental in exposing advanced countries' claims that India has been contributing substantially to the methane influx into atmosphere causing Green House Effect. Some of the facilities developed in-house have attracted scientists from advanced countries for experiments.

Dream 2047: Can you tell us about some recent measures you have undertaken to improve efficiency?

Dr. Lal: You would not imagine, till recently NPL scientists have been working on about 175 projects, many of them with very little impact. One of my first goals immediately after taking over was to bring down the numbers to about 50 so that a better focus could be given to research work. My aim is to bring it further down to some 25 – 30 quality research projects by and by. I have been working with the laboratory for so many years. And I know the high potential of its scientists.

Dream 2047: In these days, the productivity of a laboratory is measured by number of patents filed by its scientists and revenue earned from external sources. Can you tell us about NPL's achievements on these counts?

Dr. Lal: When I took over the director about one and half years ago, the external cash flow (ECF) graph was showing a downward trend. Fortunately, we could arrest this trend and right now the ECF last year was the highest in the last 10 years. Our resource generation in 2000-2001 was little more than 20% of the annual grant (Rs. 24.62 crore) we received. The revenue from testing and calibration has grown by 20% in the first nine months of the current financial year compared to the same period, last year, the highest in recent times. More importantly, we could bring down the share of salary component in the actual expenditure to ~ 52% from 55.3% in 1999-2000. The number of patents filed is also expected to go up by 50% this year.

Frankly speaking, at the moment the resources are not one of our major worries. We have enough projects. Actually there is a major upgradation project worth Rs. 19.5 crore. The concern is to spend money in proper and judicious manner. It should accelerate the growth of our competence and its linkage with national efforts for development of our country.



Dr. Krishan Lal

For any materials research and development work, a strong back up of materials characterization is essential. Advanced facilities and high quality expertise are available for characterization of materials regarding composition, purity, structure and crystal defects. Bulk materials and thin films can be characterized. Facilities for analysis of liquids and gases have also been established. Some of the sophisticated equipment have been developed indigenously. These include a five crystal X-ray diffractometer with the state-of-the-art level resolution. Fundamental investigations are being carried out on different aspects of materials characterization including those on dynamical diffraction of X-rays from 'thin' crystals of varying degrees of perfection, which has led to direct observation of forward diffracted beam in these crystals and a loss in absorption at Laue diffraction maxima. Also, applied research is carried out on advanced materials, thin films, interfaces, and micro-machined devices. Research and development work on growth and characterization of technologically important single crystals like those of bismuth germanate is also being carried out. Certified reference materials (CRMs) are being prepared to serve as quality management tools in efforts to solve crucial issues like toxic elements in water. Fifteen CRMs, named as 'Bharatiya Nirdeshak Dravyas' have already been developed.

In the field of radio and atmospheric sciences the present focus is on two broad areas. Firstly, R&D work is being conducted on minor species in the atmosphere such as NO_x , ozone, CH_4 etc. At the local level, occurrence of fog in winter in Delhi and its relationship with atmospheric pollutants is being investigated. Some of the recent activities relate to impact of pollutants on human health and effect of different agricultural practices on loading of atmosphere with minor species of concern from pollution point of view. The other main area is concerned with study of ionosphere for communications. A modern digital ionosonde technique and the effect of terrestrial obstructions on the propagation of microwaves are current areas of research. An interesting facility has been developed for detection of living bodies under concrete debris in the event of a natural disaster or any other mishap. NPL scientists are actively participating in R&D work at Antarctica.

Fundamental aspects of the phenomenon of superconductivity at high temperatures are being investigated covering the effect of substitutional impurities and irradiation. The newer developments in the field of polymers and metal-based superconductors are being taken note of. SQUIDS fabricated out of different types of superconductors have been investigated. Magnetic fields of very low intensity can be measured by employing the indigenously developed SQUIDS. NPL has developed a high level expertise in fabrication of superconducting magnets by using conventional superconducting wires. Magnets to suit different applications can be designed and fabricated. The expertise in the field of cryogenics is being utilized to establish humidity standards. The core of the experiment has been designed, developed and fabricated at NPL.

* Dr. Krishan Lal is Director of NPL. Dr. Lal has also edited the volume "The Collected Works of K. S. Krishnan".

Contd. from page 23



Lord Rayleigh



Max Theodor Felix Van Laue

KSK died on June 13, 1961.

We would like to end this write-up by quoting from an article on Krishnan by Shiv Visvanathan, a sociologist of science and who has worked on Krishnan and his NPL days:

"When NPL was being built there were two trees in front which were creating problems. The builders decided to cut them down. When the axe was about to fall, Krishnan was just driving in. He stopped, astonished and horrified and then came running up to the tree cutters jabbering in his not too articulate Hindi. Seeing Krishnan's distress, Kanvinde, the architect, also rushed to the scene. Krishnan asked them 'Why are you cutting down these trees?' The architect answered 'Sir, we thought they looked asymmetrical in the landscape'. Krishnan fell silent and then replied, 'You can still create symmetry. Not by cutting down a tree but by adding one more'. The aesthetics of the man who loved Whitehead and admired Pavlova is captured in this vignette."

References

1. *Current Science* (A monthly journal of the Indian Academy of Sciences, Bangalore) vol. 75, No. 11, 1988. This issue contains a special section on KS Krishnan brought out on the occasion of his birth centenary. The following articles in this section may be appropriate for general readers.
 - i. K.S. Krishnan : *Birth Centenary* by E.S. Raja Gopal.
 - ii. "K.S. Krishnan : A pioneer in condensed matter physics by T.V. Ramakrishnan
 - iii. K.S. Krishnan the complete physicist by R. Sundaram.
 - iv. A conversation with K.S. Krishnan on the story of the discovery of the Raman Effect by S. Ramaschshan.
 - v. The tragedy of K.S. Krishnan : A sociological fable by Shiv Visvanathan
2. *Journey into light : Life and Science of Raman* by G. Venkataraman. Indian Academy of Sciences, Bangalore, 1988.
3. *Biographical Memoirs of Fellows of the National Institute of Sciences of India* Vol. 2 National Institute of Sciences of India (presently known as Indian National Science Academy): New Delhi 1970 (The memoir of Krishnan published in this volume was written by Kathleen Lousdale and H.J. Bhabha).
4. *Some Eminent Indian Scientists (Fourth edition)* by Jagjit Singh, Publication Division, Govt of India, New Delhi . 1991.

Science Propagation through Marathi

A Report

While writing on science subjects in mother tongue, whether one should use the terminologies derived in Marathi or in Sanskrit or use them as they exist in English is a problem for the writers. For example, for sulphuric acid should one use Gandhakmla or keep it sulphuric acid as it is. Barring Tamil, all other Indian languages are Sanskrit based, then why not have the terminology based on Sanskrit, asked Mr. M.V. Kamath, President of Vigyan Prasara, Delhi, while inaugurating a two day programme on science propagation through Marathi on December 1-2, 2001. He further said that Vigyan Prasara, could establish a Translator's cell which can get best, or if possible all, original science articles written in any Indian language translated into English so that everyone has access to science articles written in India irrespective of his or her language of communication.

Dr. Bal Phondke, former director of National Institute of Science Communication (NISCOM) and a prolific science writer, while delivering the key note address at the seminar raised few questions on the need of science communication and its effective propagation. Among the points he raised were how to propagate science, for whom, what are the available mediums, which are more effective, are they available to Marathi population and so on. He reviewed the present status of science writing in Marathi. He also mentioned that the society respects scientists and hoped that scientists can do something positive for the cause of the society. All India Radio has played a major role in science propagation as compared to TV, he observed. Quoting a survey, he said science fiction writing in Marathi is very rich as compared to other Indian languages.

Mr. Laxman Londhe, initiating discussions on the key note address, said merits and demerits of any scientific discovery are not projected by science writers impartially. Dr. R. M. Shewale stressed the need for reaching scientific information to the last rung of society with the help of modern means like CD-ROM. Writing should be in a simple language as practised by Shivam Karantha, advised by Mr. A.P. Deshpande, while concluding the session.

Encyclopedias is a major reference material to the science writers and hence a special session was arranged to inform people how encyclopedias are made. Mr. A.N. Thakur, former science editor of Vishwakosh, a Govt. of Maharashtra project, said that Marathi is very rich amongst all Indian languages in encyclopedias. It has 800 different encyclopedias. Dr. Suresh Nadkari, who was associated with bibliography project of medical books published in Marathi, narrated his experiences. Mr. A.P. Marathe was the chairperson of the session, who himself has undertaken a project of making encyclopedia.

All India Radio is a major contributor in propagating science in Marathi. There are different slots for different groups of listeners like farmers, factory workers, women, students and so on and AIR caters to these groups of listeners appropriately for years together. AIR has reached to 98% people. Prof. Mohan Madwanna from Solapur stated that AIR has made friendship with rural population. Dr. Anil Mahabod from Pune narrated the programme on environment titled "Naate Nisargadi" being broadcast from Pune. Ms. Sushama Hippalgaonkar of AIR Mumbai narrated her experiences with a successful health-based programme titled "Arogyam Dhansampada". Mr. Hemant Nene who have organised many programmes on sky gazing on Radio and was happy to share

his experiences. However, he expects AIR to do much more than what is being done. Mr. Jayant Erande informed the gathering while summing up the session that AIR had a serial of 124 parts on "Evolution of Human" and of 13 parts on "Science Vision." Over a lakh of students had participated in these programmes by enrolling themselves beforehand and had participated in the examination. AIR had given awards to 10% of the student participants.

On the second day, there was a session on science propagation done by TV and other means. Mr. Nilu Damle while speaking on TV remarked that TV has to strengthen the marketing side. They are not catering to what the viewers want. Mr. Subas Naik Satam from Nehru Planetarium stated that about 90 lakh people have seen planetarium during past 25 years since it started its activities. Students like sky gazing and Nehru Planetarium meets their requirements by organising a variety of programmes. Nana Shivalkar, a graphic designer with Times of India warned that if the books do not carry sufficient illustrations and pictures, children may not like them. Hence a skillful use of pictures and illustration is necessary. Mr. Achut Dase of Nehru Science Centre took the audience to a virtual tour of science centre. Dr. S.C. Agarkar of Homi Bhabha Centre for Science Education stressed on carrying out experiments while learning/teaching a science subject. While concluding the session, Mr. Mukesh Sharma, Director, Mumbai Doordarshan, requested audience to give their valuable feedback on science-based TV programmes so that their quality could be improved.

In a session on newspapers, Mr. Niranjana Ghate expressed his happiness that newspapers are publishing a number of science articles these days. Prof. S.P. Deshpande said he wrote more than 100 articles on mathematics and these were appreciated by common readers. Dr. Anil Lachake said that we could learn more about Anthrax through newspaper columns and newspapers give information on the latest subjects and their developments. Mr. Abhijit Mule from Sakal said, although we try to write on few subjects in science supplement, there is a lot to be covered. Mr. Sanjay Latkar, editor, Lokmat, a Mumbai daily, concluded the session by remarking that Lokmat and Marathi Vidyan Parishad have agreed recently that material published in Marathi Vidyan Parishad's periodical "Patrika" be reproduced in Lokmat.

Dr. R.T. Gahukar, an agriculturist, spoke very high about Baliraja, a magazine devoted to agricultural science. Dr. Ranjan Garge, microbiologist from Aurangabad wanted to know whether magazines should inform the public about basics of science or the latest developments in science or latest development on them. Prof. R.V. Sovani praised Marathi Vidyan Parishad Patrika which has been in print for the last 35 years. Mr. P.B. Bhosale explained that a large number of farmers in the state read Baliraja magazine.

Mr. Prabhakar Deodhar, President, Marathi Vidyan Parishad, concluded the two day seminar by saying that Marathi Vidyan Parishad is going to prepare a band of 5000 science propagators through out the state of Maharashtra shortly.

Dr. Subodh Mahanti of Vigyan Prasara proposed a vote of thanks.

A.P. Deshpande, Honorary Secretary, Marathi Vidyan Parishad

♦ ♦ ♦